Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Design of Lithium Ion Source for Ion Beam Irradiation and Generation of 14-MeV Neutrons

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1. Introduction

Lithium ion beam can be used to irradiate ion beam and to produce 14-MeV neutrons. As an example of ion beam irradiation, lithium ion beam implantation with energy of 100 keV is used as an important tool in silicon defect engineering [1]. In the case of 14-MeV neutrons, a lithium ion beam accelerated to more than hundreds keV is irradiated to deuterium to produce neutrons. In general, 14 MeV neutrons were obtained by fusion reactions of deuterium and tritium, but in this case there were difficulties in dealing with tritium. If the neutrons are obtained by accelerating deuterium and irradiating it in lithium, the problem of ion sources or accelerator body being contaminated by tritium produced by the deuterium-deuterium fusion reaction. Fig. 1 shows the fast neutron energy spectrum of deuterium-lithium reactions calculated by Geant4 computer code.

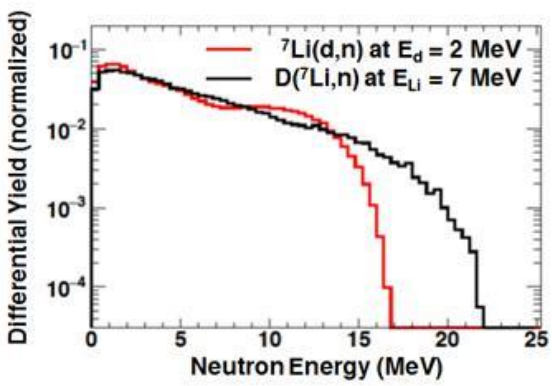

Fig. 1. Neutron energy spectrum (Geant4 code).

An ion source has been developed to obtain lithium ions for these purposes [2]. The lithium beam current of ion sources was determined to be around 1 mA and the extraction voltage to be 14 kV. In the case of beam energy, the latter acceleration is intended to obtain the necessary energy.

2. Design

2.1 Type of Ion Source

There are many different ways to get lithium ions. There is a method of evaporation of lithium chloride to produce plasma and obtain ion beam from it, and a method of obtaining ion beam directly from the surface using surface ionization effect. In the latter case, it is possible to obtain an ion beam by evaporating lithium metal in oven and supplying lithium vapor to heated tungsten surface, and heating solid containing lithium. Contamination may be a problem for plasma ion sources, and for thermionic emission-type ion sources with ovens, it has advantages that can be used for long periods of time but has a rather complex structure. The advantage of the thermionic emission from solid is that the ion source itself is very simple, but the limited amount of lithium contained in the solid has the disadvantage of having to replace the ion emission anodes periodically. This ion source is designed as a thermionic emission type considering the simplicity of the device.

2.2 Size of Anode

The best emitter is a mineral called lithium alumiosilicates. Current conditions of 1-10 mA/cm^2 are required at operating temperatures of about 1,000 ℃. It was decided to use an anode with a diameter of 15 mm, in which case the ion-emitting surface area is 1.8 cm^2. Therefore, it is expected that the operating temperature of the ion source for 1 mA will be below 1000 ℃. Fig. 2 shows the anode to be used.

Fig. 2. Anode for lithium ion source.

2.3 Geometry of Electrodes

For electrodes of the thermionic emission type, electrode shapes are similar to an electron gun. The emission surface from which the ion is released and the focus electrode to suppress the ion divergence are placed at positive high voltages. The extracted ion beam will proceed with free space through a hole in the ground electrode located in the ground potential. The distance between the emission surface and the ground electrode shall be long enough to prevent high voltage discharge, and short enough to have the space charge limiting current larger than 1 mA. So it is necessary to determine the optimum distance between these.

Considering the extraction voltage of 14 kV and 1 mA, the distance between the focus and ground electrodes was determined to be 5 mm. The angle of the vertical line of the focus electrode and the anode is 60 degrees. Based on these electrodes dimensions and applied voltages, a computer simulation using IGUN code [2] confirmed that beams of about 1 cm in diameter and 1 mA can be obtained from the ion source exit as shown in Fig. 3.

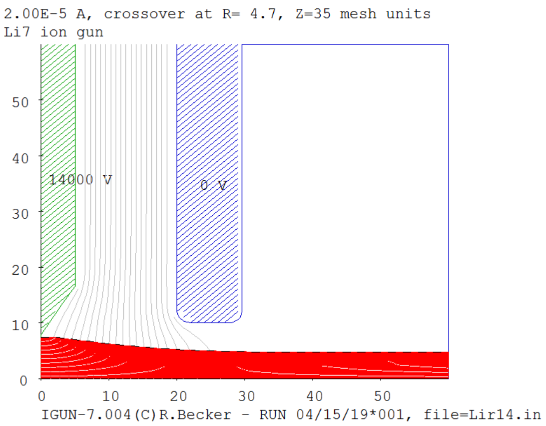

Fig. 3. Lithium ion beam trajectory simulated with IGUN code.

2.4 Power Supplies for Ion Source

The maximum beam extraction voltage is 20-kV DC, and the ion emitting anode is heated by AC current through a high voltage insulation transformer with 20-kV insulation voltage. The temperature of the anode surface is expected to reach 1100 ℃ when approximately 11.2 A is applied to the anode. Since the primary and the secondary windings of the high voltage insulation transformer are both 220V, the voltage control will be performed by installing a 220V:20V transformer on the secondary winding and placing 220-V slidac on the primary side of the high voltage insulation transformer.

3. Conclusions and Future Plan

Lithium ion sources to be used for ion beam irradiation and the generation of 14-MeV neutrons were designed. The material and size of the anode to obtain a 14-kV extraction voltage and 1 mA extraction beam current were determined, and the electrode geometry was determined through computer simulation.

Based on this design, a lithium ion source will be manufactured and tested at the test stand in Fig. 4. The test stand consists of a high voltage terminal, an analyzing electromagnet, an acceleration column, an irradiation chamber, power supplies and a vacuum system, which can accelerate the beam up to 200 kV as shown in Fig. 5.

Fig. 4. Test stand for lithium ion source.

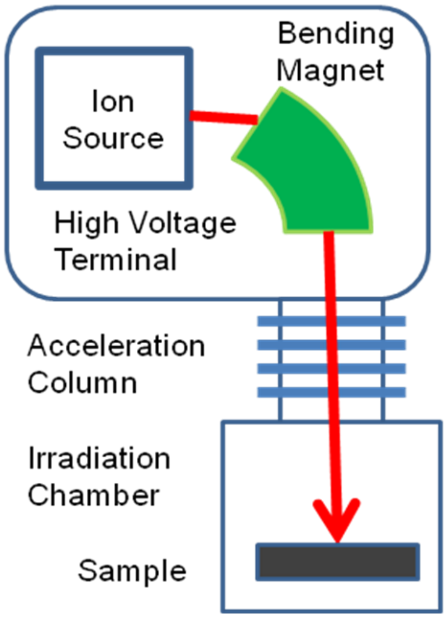

Fig. 5. Configuration of ion source test stand.

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